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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2833

AN ANALYSIS OF NORMAL ACCELERATIONS AND AIRSPEEDS OF ONE TYPE OF TWIN-ENGINE TRANSPORT AIRPLANE IN COMMERCIAL OPERATIONS OVER A NORTHERN TRANSCONTINENTAL ROUTE

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SUMMARY

Normal-acceleration and airspeed data obtained for one type of twin-engine transport airplane in commercial operations over a northern transcontinental route are analyzed to determine the gust and gust-load experiences of the airplane. The acceleration increments experienced equaled or exceeded the limit-gust-load factor, on the average, twice (once positive and once negative) in about 7.5×10^6 flight miles, and an effective gust velocity of 30 feet per second was equaled or exceeded twice in about 1×10^6 flight miles. The data indicate that the maximum gusts and gust loads experienced in the winter were roughly 10 percent higher than those experienced in the summer on this route.

@ 200 mph ≈ 39000 hrs

≈ 4,000 hrs

Martin 202 airplane

INTRODUCTION

As part of a continuing study of the gusts and gust loads experienced by transport airplanes in routine commercial operations, airspeed and normal-acceleration data have been obtained for one type of twin-engine transport airplane in transcontinental operations over the northern part of the United States. The data cover a period of about $1\frac{1}{2}$ years and consist of 388 records for about 39,000 flight hours. These data are almost a complete history of this type of airplane for the period covered inasmuch as the 24 airplanes instrumented constituted nearly all the airplanes of this type that were ever built.

The data have been analyzed to determine the frequency of occurrence of given values of acceleration increments, effective gust velocities, and maximum airspeeds. The values of special interest in the analysis are assumed to be the average flight miles required to equal

or exceed the limit-load-factor increment, the effective gust velocity of 30 feet per second, and the placard never-exceed speed. The variation of these values with season and operating conditions is also indicated and a comparison is made with operations on other routes.

SYMBOLS

A	aspect ratio, b^2/S
S	wing area, sq ft
b	wing span, ft
K	gust alleviation factor
a	slope of lift curve per radian
ρ_o	air density at sea level under standard conditions, slugs/cu ft
U_e	effective gust velocity, fps
V	indicated airspeed, mph
V_L	design maximum level-flight speed (indicated), mph
V_o	indicated airspeed at which maximum positive or negative acceleration increment occurs on a V-G record, mph
V_p	probable airspeed at which the maximum acceleration can be expected to occur, mph
W	gross weight, lb
Δn	normal-acceleration increment measured at center of gravity, g units
$1/\alpha$	scale parameter of distribution of extreme values (ref. 1)
u	location parameter of distribution of extreme values (ref. 1)
α_3	coefficient of skewness of distribution (ref. 2)
σ	standard deviation for distribution of a variable (ref. 2)
s	best small sample estimate of standard deviation (ref. 1)
P	computed probability of occurrence of a given value of a variable

Subscripts:

LLF value for limit load factor

max maximum value read or computed from V-G record

A bar over a symbol denotes the mean value of the variable for a given set of observations.

An asterisk indicates that the value has been corrected for dynamic response.

APPARATUS AND SCOPE OF DATA

The airplanes used to obtain the data, which were collected with an NACA V-G recorder, were twin-engine transports engaged in commercial operations. This type of airplane had the following characteristics:

Maximum take-off weight, lb	39,900
Wing area, sq ft	864
Wing span, ft	93.3
Mean aerodynamic chord, ft	10.1
Slope of lift curve per radian $\left(\text{computed from } \dfrac{6A}{A + 2}\right)$	5.00
Aspect ratio	10.1
Limit-gust-load-factor increment (computed), g units	1.70
Design maximum level-flight speed at sea level, mph	256
Never-exceed speed, mph	292

These values were obtained from the manufacturer's design data and operating manual or were computed, as indicated in the table. The limit-load-factor increment of 1.70g was computed according to the formula in reference 3 by using the computed slope of the lift curve.

The airplanes were operated at an average pressure altitude of 6,500 feet although individual flights were made at pressure altitudes of a few thousand to approximately 10,000 feet. The flights were made from Seattle, Wash. to New York or Washington, D. C. Individual flights, based on information obtained from the operator, averaged approximately 200 miles, or 1 hour, in length.

During the period from December 1948 to April 1950, 439 records were collected from all (24) airplanes of this type in use on this route. These records represent a total of approximately 42,000 flight

hours or 8.5×10^6 flight miles based on an estimated average airspeed of approximately 204 miles per hour. Inasmuch as the method of analysis used requires that the record time be reasonably constant, only those records containing from 80 to 120 hours each were used in the analysis. On this basis, the number of usable records was reduced to 388 representing approximately 39,000 flight hours or 7.8×10^6 flight miles. This procedure of using a consistent record time resulted in a loss of only 11 percent of the records and about 7 percent of the record time.

Shortly after the data collection was initiated, the airplanes of this type were placed under special cautionary restrictions in order to reduce the gust loads. These regulations stated: "do not operate the aircraft in excess of ninety percent of the placard V_{ne} [never-exceed speed] and V_{no} [normal operating speed] speeds . . . In the event any turbulence is encountered in flight, immediately reduce the speed to a maximum of 170 MPH and further reduce the speed to a maximum of 150 MPH dependent upon the severity of the turbulence." These restrictions, effective April 6, 1949, continued in force on individual airplanes until May 20, 1949 to October 13, 1949. The possible influence of these regulations on the gusts and gust loads experienced is discussed subsequently.

ANALYSIS AND RESULTS

The analytical procedures used in the analysis are described in references 1 and 4. The values read from the V-G records for the analysis were the maximum positive and negative acceleration increments Δn_{max} occurring above 140 miles per hour, their corresponding indicated-airspeed value V_o, and the maximum indicated airspeed V_{max}. The acceleration increments at airspeeds below 140 miles per hour were not read in order to avoid including the effects of maneuvers during take-off and approach and impact shocks during landing. Reference 5 indicates that a very small part of the flight time for this type of airplane was spent below an airspeed of 140 miles per hour. The maximum positive and negative effective gust velocities for each record were computed from the acceleration increments and the corresponding airspeed which gave the maximum value in the sharp-edge-gust formula

$$U_{e_{max}} = \frac{2\Delta n \frac{W}{S}}{1.47\rho_o aKV_o}$$

Inasmuch as the weight was not known at the time of each acceleration, an average operating weight of 85 percent gross weight was assumed for these calculations.

The total frequency distributions and the statistical parameters of each distribution for Δn_{max}, $U_{e_{max}}$, V_o for Δn_{max}, and V_{max} are given in tables I, II, III, and IV, respectively. Probability curves based on the theory of extreme values were used to describe the frequency distributions of maximum acceleration increments and maximum gust velocities in tables I and II. The mean, the small sample estimate of standard deviation s, the scale parameter of the distribution of extreme values $1/\alpha$, and the location parameter of the distribution of extreme values u are listed in these tables. Pearson type III curves (ref. 4) were used to describe the frequency distributions of both V_o and V_{max}. The mean, the standard deviation σ, and the coefficient of skewness α_3 used in fitting the Pearson type III curves are given in tables III and IV.

In order to preserve the integrity of the original data for the purpose of statistical calculations, the measured center-of-gravity acceleration increments Δn_{max} and the corresponding effective gust velocities $U_{e_{max}}$, as well as the statistical parameters for these distributions, are given in the tables. When the data were plotted, however, the dynamic effects of wing flexibility were removed from the center-of-gravity measurements Δn by the relation

$$\Delta n^* = \frac{\Delta n}{1.2}$$

where Δn^* is the airplane acceleration increment. This reduction was based on the results of a flight investigation of the effect of transient wing response in rough air upon acceleration measurements at the center of gravity for this type of airplane (ref. 6). The results indicate that under dynamic conditions the center-of-gravity acceleration measurements in rough air are about 20 percent higher, on the average, than the wing nodal-point acceleration which is considered to be the true translatory acceleration of the airplane. The results in reference 6 were applied in the present investigation, and the airplane acceleration increments Δn^* were obtained from the center-of-gravity measurements Δn by the relation given.

The theoretical probability distribution and the data of V_{max}, Δn_{max}, and $U_{e_{max}}$ were transformed to curves of average flight miles required to equal or exceed given values of each variable V, Δn^*, and U_e^* by multiplying $1/P$ by an assumed cruising speed of 204 miles per hour and the average flight hours per record. The distributions of Δn

and U_e were then corrected for dynamic response to give distributions of Δn^* and U_e^*. The correction of U_e to U_e^* was made in a manner analogous to that used for the acceleration increments by using the relation

$$U_e^* = \frac{U_e}{1.2}$$

Inasmuch as the present analysis is concerned mainly with the larger values of Δn^*, U_e^*, and V_{max}, only those parts of the transformed curves representing the larger values are shown in figures 1 to 7. These curves indicate the average flight distance required to equal or exceed a given value. The curves of Δn^* and U_e^* indicate the distance required to equal or exceed the value twice, once positive and once negative, since two values were read from each record and combined into one distribution. The limitations of using these transformed probability curves as curves of average flight miles required to equal or exceed given values have been discussed in reference 7. This reference indicates that estimates of the flight miles required to exceed the larger values, based on the distribution of the observed maximums, are not seriously in error.

The present sample of 388 satisfactory records and about 39,000 flight hours is of sufficient size to permit the analysis of data by seasons of the year and periods during which operating practices may have changed. The data were divided accordingly into two seasons, March 21 to September 21 which was classed as the summer season and September 22 to March 20 which was classed as the winter season. These groupings were made since analyses indicated little differences between smaller groupings within the 6-month "seasons." The data were also divided into three groups which correspond to the period before the airspeed restriction was placed on the airplane operation in turbulent air (period I), the period of restricted airspeed (period II), and the period after the restriction was removed (period III) in order to determine the effect of operating practices on the gust-load experience of airplanes of this type. These distributions are given in tables I to IV with their appropriate statistical parameters. Records were normally put in a period or season in which most of the flight time occurred. When it was difficult to determine this fact, the records were omitted from the groupings.

In order to obtain a measure of the operating speeds in rough air, the probable speed at which the maximum acceleration increment can be expected to occur V_p (the airspeed at which the frequency distribution of V_o has the maximum value) was calculated from the statistical

parameters of the V_o distributions in table III. This value of probable speed is listed in the table together with the statistical parameters.

PRECISION AND STATISTICAL RELIABILITY

The precision of the NACA V-G recorder and the limitations of the method of analysis are discussed in reference 8. The instrument errors are assumed not to exceed ±0.2g for acceleration nor 3 percent of the maximum airspeed range of the instrument. These instrument errors are not considered serious since they should be random because of the large number of instruments used (total of 41) and should average out in the analysis.

Inasmuch as the values of Δn^* and U_e^* reach values corresponding to the limit-gust-load-factor increment of 1.70g and the design effective gust velocity of 30 feet per second, respectively, and the samples are large, past experience and statistical tests indicate that the estimates of the flight miles required to exceed these values as given in figures 1 and 2 are accurate to within ±30 percent. When the data are divided into groups, the estimates become less accurate, or conversely, the reliability of the curves decreases. Statistical tests indicate that for the results shown in figures 6 and 7, the least reliable of the present results, the estimates of the flight miles are accurate to within one-half and twice the values given.

For the distributions of maximum airspeed, no analytical methods are readily available for determining the reliability of extrapolated estimates. In figure 3, only one point extended beyond the never-exceed speed of 292 miles per hour. The frequency of exceeding this value, therefore, had to be estimated by extrapolation. On the basis of past experience, this extrapolation is believed to be justified, provided the estimates thus obtained are used only as an indication of the order of magnitude.

DISCUSSION

Acceleration experience.- Examination of figure 1 indicates that a value of Δn^* equal to the calculated limit-gust-load increment of 1.70g will be equaled or exceeded twice, once positive and once negative, in 7.5×10^6 flight miles. This value together with the results for other transport operations is, for comparison, presented in the following table:

Operation	Period	Flight miles to exceed Δn_{LLF} twice
Northern United States	1948 to 1950	7.5×10^6
Eastern United States (ref. 7)	1947 to 1948	0.6×10^6
Caribbean-South American (ref. 9)	1947 to 1949	5.6×10^6
Trans-Pacific (ref. 9)	1947 to 1949	2000×10^6
Three separate routes (ref. 10)	1941 to 1945	2.7×10^6 to 7.5×10^6

The table indicates that the gust-load experience on the transcontinental route in the northern United States was, with one exception, less severe than the other operations covered. The one exception, the trans-Pacific operations, as indicated in reference 9, had an unusually mild load history as a result of the combination of low operating airspeeds and the low turbulence levels.

Gust experience.- Figure 2 indicates that an effective gust velocity U_e^* of 30 feet per second was exceeded twice in 1×10^6 flight miles. This value of flight miles is not directly comparable to results from other investigations because previous work has, in some instances, used a different value of gust velocity and obtained the flight miles by a different technique. This technique consisted of determining the flight miles required to exceed the acceleration increment due to an effective gust velocity of 37.5 feet per second at the most probable speed at which gusts will be encountered V_p. This method of obtaining the gust experience gives a reasonable estimate of the miles required to exceed a 37.5-foot-per-second gust. For comparison, therefore, the results from other operations are tabulated with the present results of the flight miles required to exceed the larger gust velocity:

Operation	Period	Flight miles to exceed a gust of 37.5 fps twice
Northern United States . .	1948 to 1950	9×10^6
Eastern United States (ref. 7)	1947 to 1948	7×10^6
Caribbean-South American (ref. 9)	1947 to 1949	1×10^6
Trans-Pacific (ref. 9) . .	1947 to 1949	90×10^6
Three separate routes (ref. 10)	1941 to 1945	2×10^6 to 20×10^6

From this table and reference 10 the gust experience on a route across the northern United States appears to be generally less severe than on most other operations from 1941 to the present. Table III indicates that the probable speed of encountering the maximum acceleration increment per 100 hours of flight (the approximate record time) was 193 miles per hour. This speed is about 75 percent of the maximum speed in level flight. Reference 11 indicates that the probable speed for present-day aircraft averages approximately $0.8V_L$. The indications are, therefore, that this type of airplane encountered the maximum gust velocities at a lower airspeed than other aircraft. This reduction would tend to lower the load experience for the present operations.

An examination of figure 3 indicates that the never-exceed speed of 292 miles per hour would be equaled or exceeded, on the average, once in approximately 1×10^8 flight miles. Although this value should be taken only as an indication of the order of magnitude of the flight miles because of the extrapolation required for the higher airspeeds (table IV indicates that only five records contained maximum airspeeds above 270 miles per hour), it is considerably greater than the corresponding values obtained for other modern types of airplanes (refs. 7 and 9) and thus indicates less tendency toward excessive airspeeds for the present operations. This tendency toward avoiding excessive speed may have resulted in part from the speed regulations placed upon the airplane.

Seasonal effects.- Figure 4 indicates that the winter season produced a more severe gust-load history on the airplane than did the summer season. Statistical tests have indicated that the difference between the data for the two seasons is significant. The figure indicates that in 1×10^7 flight miles an acceleration increment Δn^* of 1.66g and 1.81g will be equaled or exceeded in summer and winter seasons, respectively. Thus, the value for the winter season represents a 9-percent increase over the results for the summer season.

The difference in the acceleration increments could be due to several factors, such as variations in airspeed practices, turbulence, or weight conditions during the two seasons. Figure 5 indicates that in 1×10^7 flight miles gust velocities of 40 and 35 feet per second were equaled or exceeded in winter and summer, respectively. These values represent an increase of about 12 percent in gust intensities for the winter season over the results for the summer season. Inasmuch as the airspeeds were about the same for the two seasons (table III), the larger loads experienced during the winter season appear to be caused by the more severe gusts encountered in the winter operations.

Effect of special operating restriction.- Comparison of the load experience for the three periods (fig. 6) indicates that little difference occurred between the load experiences for periods I and II (the pre-restriction period and the restriction period, respectively). Statistical tests indicate that a significant difference exists, however, between the gust-load experience for period III and each of the other two periods. The maximum acceleration increment which will be exceeded in 1×10^7 flight miles is approximately 20 percent greater in period III than in period II.

For the data presented in figure 7, statistical tests indicate a significant difference between the gust experiences of periods II and III, but any other combinations present differences of doubtful statistical significance. The maximum gust velocity of 40 feet per second in 1×10^7 flight miles for period III represents an increase of 25 percent above the comparable value (32 feet per second) for period II. Table III indicates that the probable speeds of encountering the maximum acceleration increments are approximately the same for the three periods and would have only a small effect on the differences in the acceleration increments encountered. The gust loads increased significantly from period II to period III when the restrictions were removed (see fig. 6). Inasmuch as no airspeed changes were apparent (see table III), the gust-loads data indicate flights through more turbulent air in period III at the same airspeed as previously used. Apparently, the severity of the gusts encountered had been reduced during periods I and II by either avoidance of turbulent areas in flight or by cancellation of flights.

It is somewhat surprising that table III indicates no airspeed changes among the results for the different periods inasmuch as the regulations went into effect 3 months after the sample collection began. However, the airspeeds during the entire sample period were low, 75 percent of V_L, and this fact suggests that, even prior to the regulations, the operator or pilots had knowingly or unknowingly placed voluntary restrictions on the airplane operations.

SUMMARY OF RESULTS

An evaluation of 39,000 hours of V-G records from normal operations of a twin-engine transport airplane in commercial operations over a northern transcontinental route yielded the following results:

1. An acceleration increment equal to the calculated limit-load-factor increment of 1.70g was equaled or exceeded, on the average, twice, once positive and once negative, in 7.5×10^6 flight miles.

2. An effective gust velocity of 30 feet per second was equaled or exceeded twice, on the average, in 1×10^6 flight miles.

3. The probable airspeed at which the maximum acceleration increment was experienced per 100 hours of flight was 193 miles per hour or 75 percent of the design maximum level-flight speed.

4. The present results indicate that the gust loads experienced, the gusts encountered, and the operating speeds were generally lower for operations of this type than for other operations since 1941.

5. The winter season, September 22 to March 20, produced roughly 10 percent larger maximum gust and acceleration increments than did the summer period.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 19, 1952.

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TABLE I

FREQUENCY DISTRIBUTIONS AND STATISTICAL PARAMETERS OF Δn_{max}

BY SEASONS AND PERIODS

Acceleration increment, Δn_{max}, g units	Number of observations					
	Total	Summer	Winter	Period I	Period II	Period III
0.4 to 0.5	1	--	1	--	--	1
.5 to .6	4	2	2	1	--	2
.6 to .7	14	3	11	8	1	5
.7 to .8	72	38	33	15	10	43
.8 to .9	139	55	82	47	25	58
.9 to 1.0	149	62	87	49	26	69
1.0 to 1.1	157	67	90	46	36	70
1.1 to 1.2	82	37	44	22	17	42
1.2 to 1.3	60	24	36	16	10	32
1.3 to 1.4	40	20	20	12	10	17
1.4 to 1.5	30	11	19	7	1	21
1.5 to 1.6	8	1	7	1	--	6
1.6 to 1.7	10	1	9	2	1	7
1.7 to 1.8	3	1	2	1	--	2
1.8 to 1.9	1	--	1	1	--	--
1.9 to 2.0	2	1	1	--	--	2
2.0 to 2.1	1	--	1	--	--	1
2.1 to 2.2	1	--	1	--	--	1
2.2 to 2.3	---	--	--	--	--	--
2.3 to 2.4	1	1	--	--	[a]1	--
2.7 to 2.8	1	--	1	--	--	1 — Not plotted
Totals	776	324	448	228	138	380
$\overline{\Delta n}_{max}$	1.039	1.0256	1.050	1.017	1.0259	1.0587
$1/\alpha$	0.1874	0.1709	0.2028	0.1650	0.1375	0.2074
u	0.9308	0.9270	0.9329	0.9219	0.9465	0.9390
s	0.2404	0.2192	0.2600	0.2116	0.1764	0.2660

[a]Point omitted in calculations.

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TABLE II

FREQUENCY DISTRIBUTIONS AND STATISTICAL PARAMETERS OF $U_{e_{max}}$

BY SEASONS AND PERIODS

Gust velocity, $U_{e_{max}}$, fps	Number of observations					
	Total	Summer	Winter	Period I	Period II	Period III
12 to 14	8	1	7	3	--	4
14 to 16	21	9	12	10	1	10
16 to 18	74	35	39	23	10	37
18 to 20	115	50	65	27	21	58
20 to 22	152	70	80	47	30	72
22 to 24	118	56	62	33	28	52
24 to 26	125	48	76	37	22	62
26 to 28	61	23	38	20	14	25
28 to 30	36	16	20	12	8	16
30 to 32	25	7	18	7	1	15
32 to 34	15	3	12	3	1	11
34 to 36	10	4	6	3	1	6
36 to 38	5	1	3	1	--	4
38 to 40	2	--	2	1	--	1
40 to 42	3	--	3	--	--	3
42 to 44	3	--	3	1	--	2
44 to 46	1	--	1	--	--	1
46 to 48	---	--	--	--	--	--
48 to 50	1	1	--	--	[a]1	--
50 to 52	1	--	1	--	--	1
Total	776	324	448	228	138	380
$\overline{U}_{e_{max}}$	23.02	22.463	23.3974	22.77	22.75	23.32
$1/\alpha$	3.9782	3.5250	4.2926	3.7703	2.8205	4.3465
u	20.724	20.4284	20.9197	20.5958	21.1238	20.8070
s	5.1022	4.5210	5.5054	4.8356	3.6174	5.5746

[a]Point omitted in calculations.

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TABLE III

FREQUENCY DISTRIBUTIONS AND STATISTICAL PARAMETERS

OF V_o FOR Δn_{max} BY SEASONS AND PERIODS

Airspeed, V_o, mph	Number of observations					
	Total	Summer	Winter	Period I	Period II	Period III
140 to 150	64	24	39	16	12	36
150 to 160	64	26	38	21	12	30
160 to 170	71	29	41	22	10	37
170 to 180	63	19	44	27	8	25
180 to 190	96	42	54	22	21	47
190 to 200	94	45	49	20	20	50
200 to 210	128	62	65	24	28	72
210 to 220	93	32	60	38	12	41
220 to 230	61	28	33	19	9	30
230 to 240	32	12	20	16	3	9
240 to 250	9	5	4	2	3	3
250 to 260	1	--	1	1	--	--
260 to 270	---	--	--	--	--	--
Total	776	324	448	228	138	380
$\overline{V}_o$	190.68	191.67	190.04	191.97	190.00	189.395
σ	26.105	25.568	26.432	27.563	25.2590	25.4720
α_3	-0.2113	-0.1928	-0.0822	-0.0558	-0.1578	-0.2057
V_p	193.23	194.13	191.01	192.74	192.00	192.01

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TABLE IV

FREQUENCY DISTRIBUTION AND STATISTICAL PARAMETERS OF V_{max}

BY SEASONS AND PERIODS

Indicated airspeed, V_{max}, mph	Number of observations					
	Total	Summer	Winter	Period I	Period II	Period III
220 to 225	2	1	1	1	--	1
225 to 230	1	--	1	--	--	1
230 to 235	10	5	5	--	1	9
235 to 240	28	19	8	--	9	19
240 to 245	79	50	29	3	20	53
245 to 250	91	34	56	24	16	46
250 to 255	77	23	54	31	13	28
255 to 260	58	17	41	32	4	21
260 to 265	31	8	23	19	3	8
265 to 270	6	2	4	3	2	1
270 to 275	2	1	1	--	--	2
275 to 280	1	--	1	1	--	--
280 to 285	--	--	--	--	--	--
285 to 290	1	1	--	--	1	--
290 to 295	--	--	--	--	--	--
295 to 300	--	--	--	--	--	--
300 to 305	--	--	--	--	--	--
305 to 310	1	1	--	--	--	1
Total	388	162	224	114	69	190
V_{max}	249.65	247.6350	251.138	254.6055	247.8625	247.3160
σ	9.4025	9.8115	8.034	6.8150	8.8595	9.2105
α_3	0.3542	1.9090	-0.1688	-0.5198	1.5627	1.5899
V_p	247.99	238.270	251.808	256.3767	240.9402	240.001

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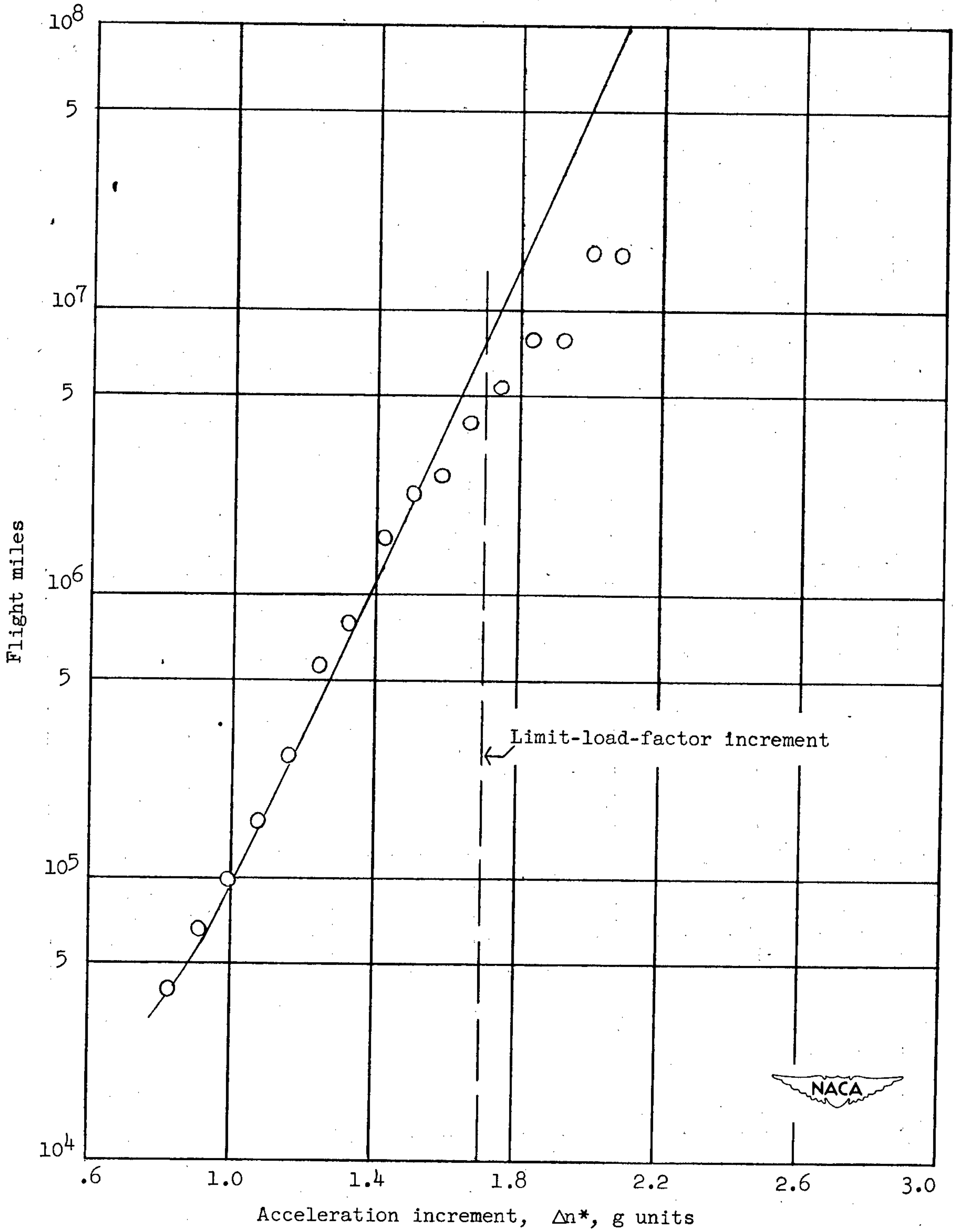

Figure 1.- Average flight miles required for a maximum positive and negative acceleration increment to equal or exceed a given value.

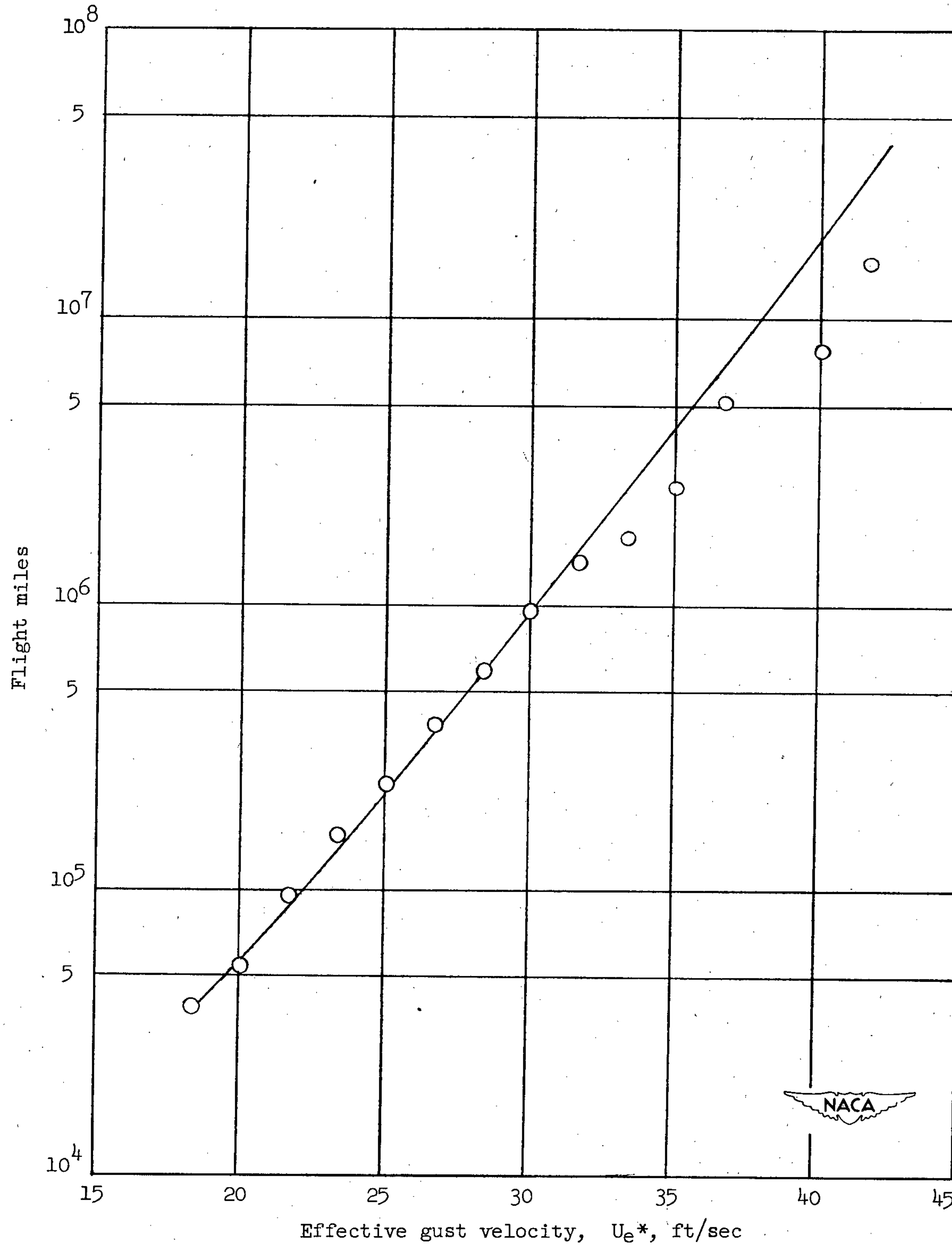

Figure 2.- Average flight miles required for a maximum positive and negative effective gust velocity to equal or exceed a given value.

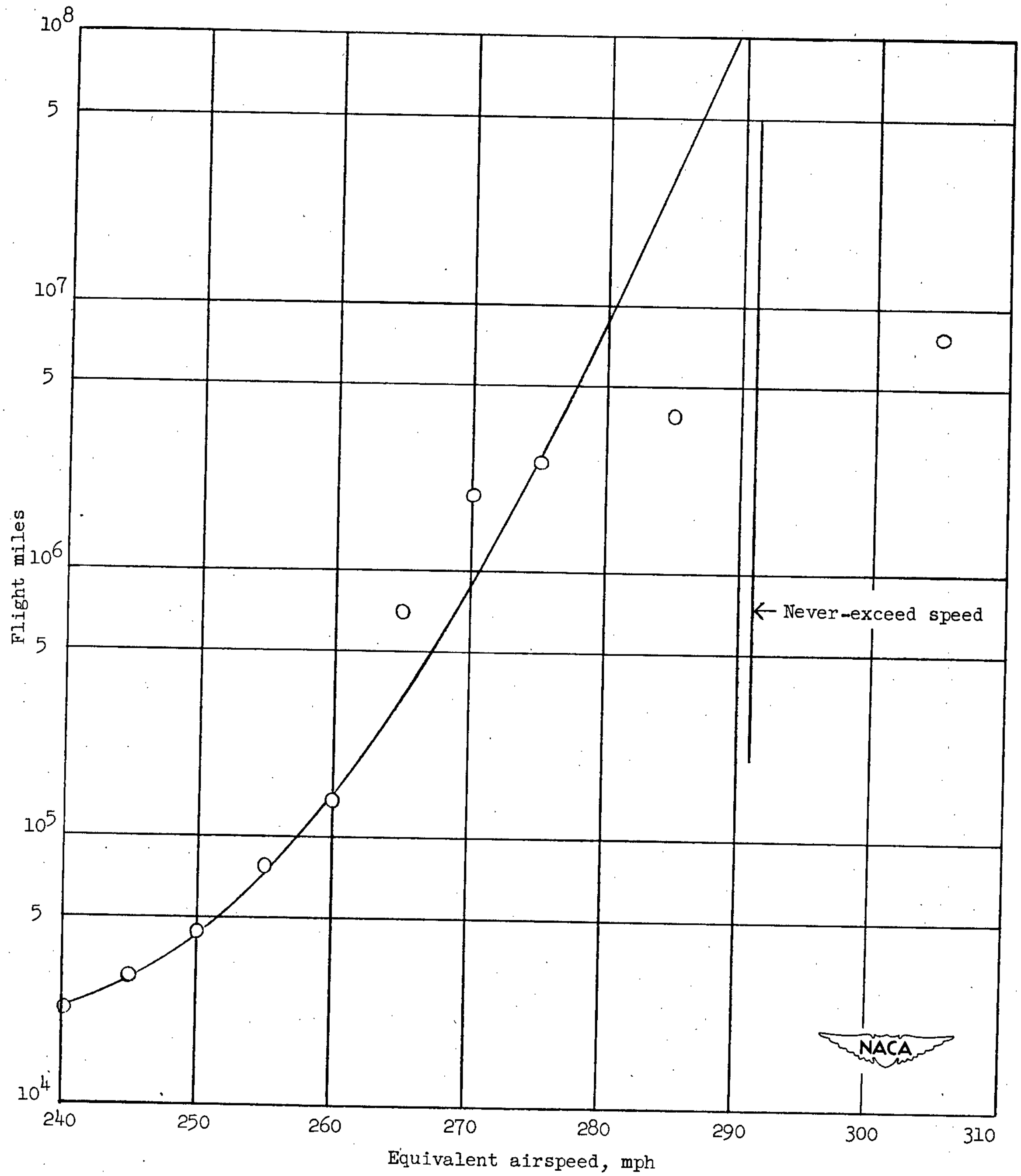

Figure 3.- Average flight miles required for a maximum airspeed to equal or exceed a given value.

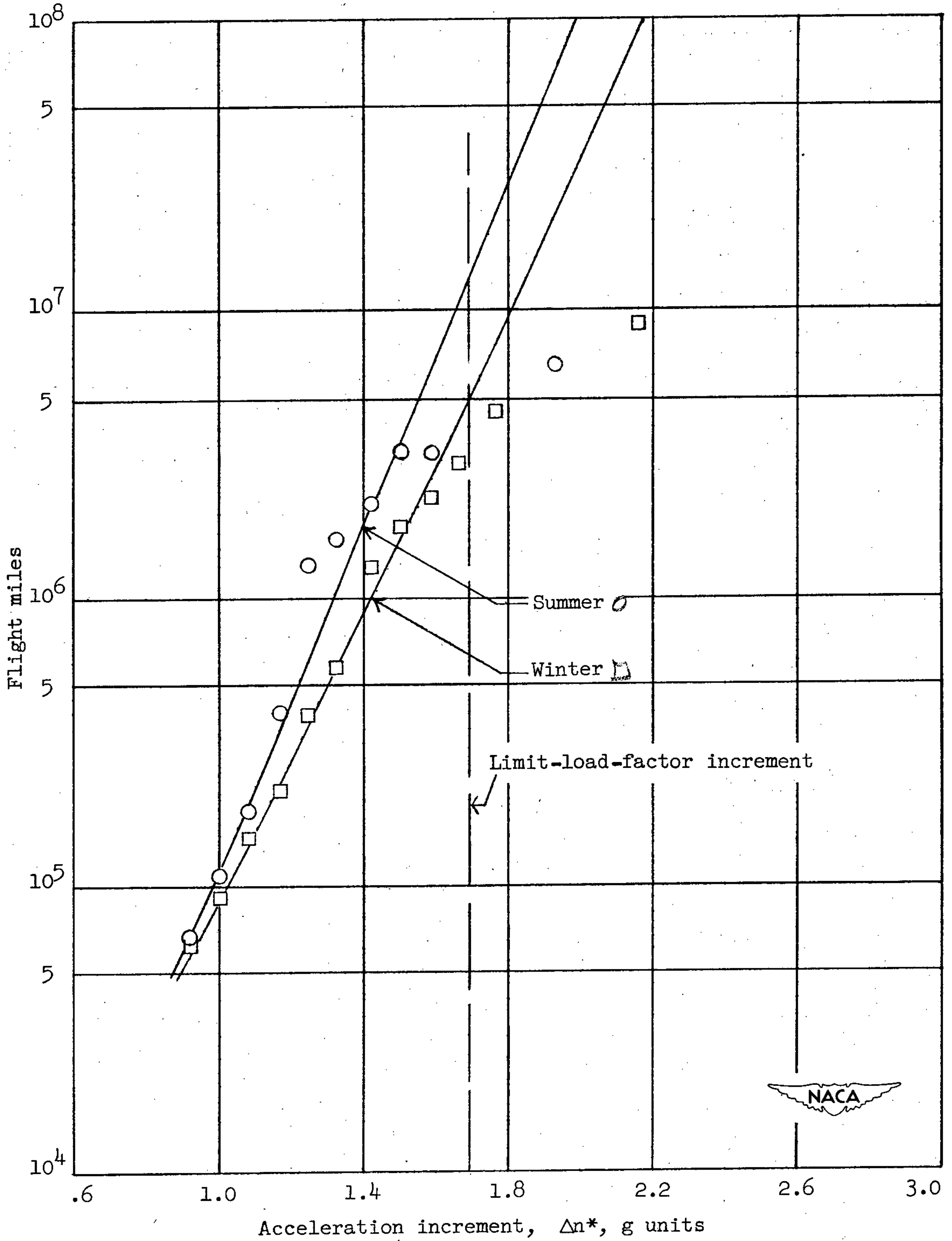

Figure 4.- Average flight miles required for a maximum positive and negative acceleration increment to equal or exceed a given value by season.

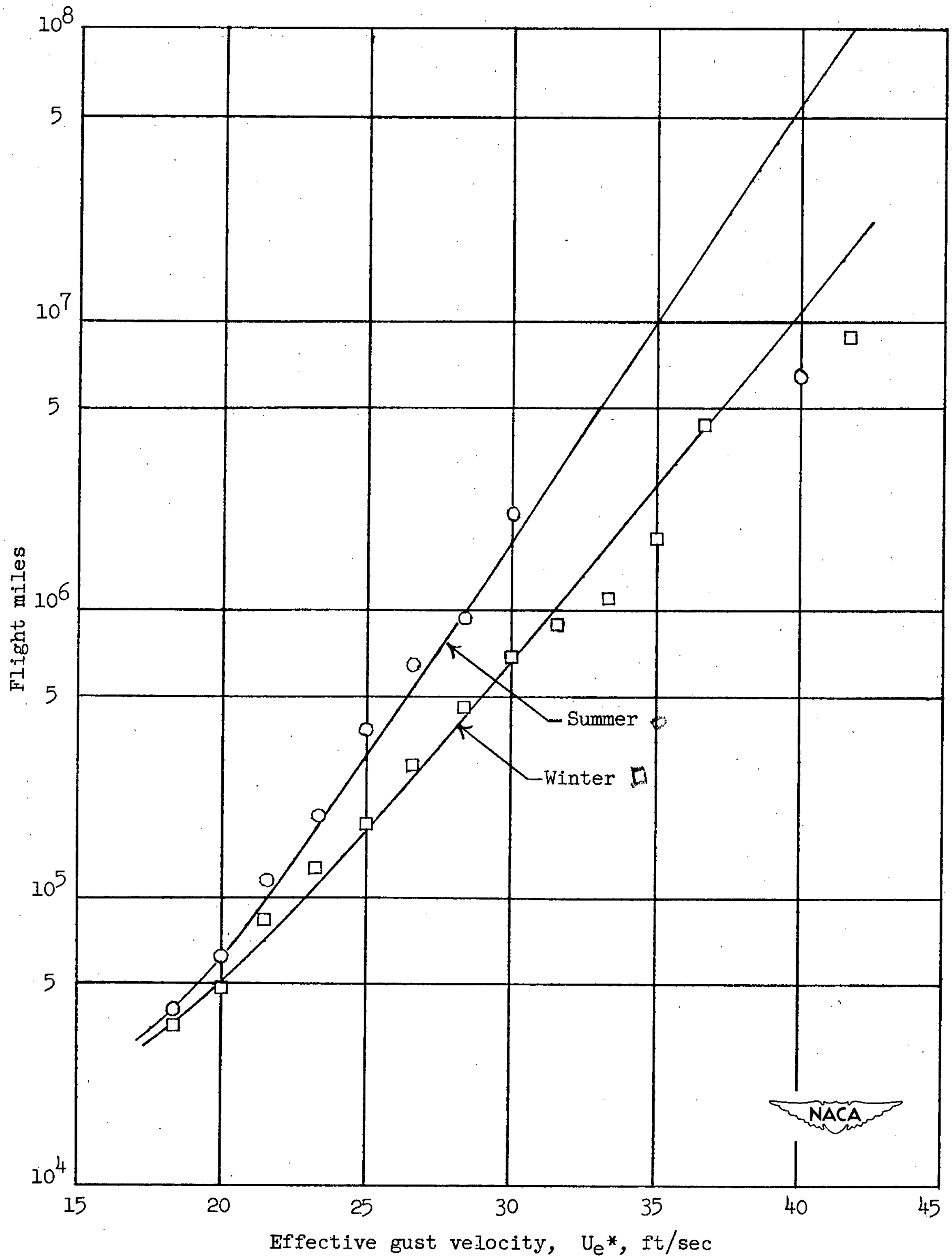

Figure 5.- Average flight miles required for a maximum effective gust velocity to equal or exceed a given value by season.

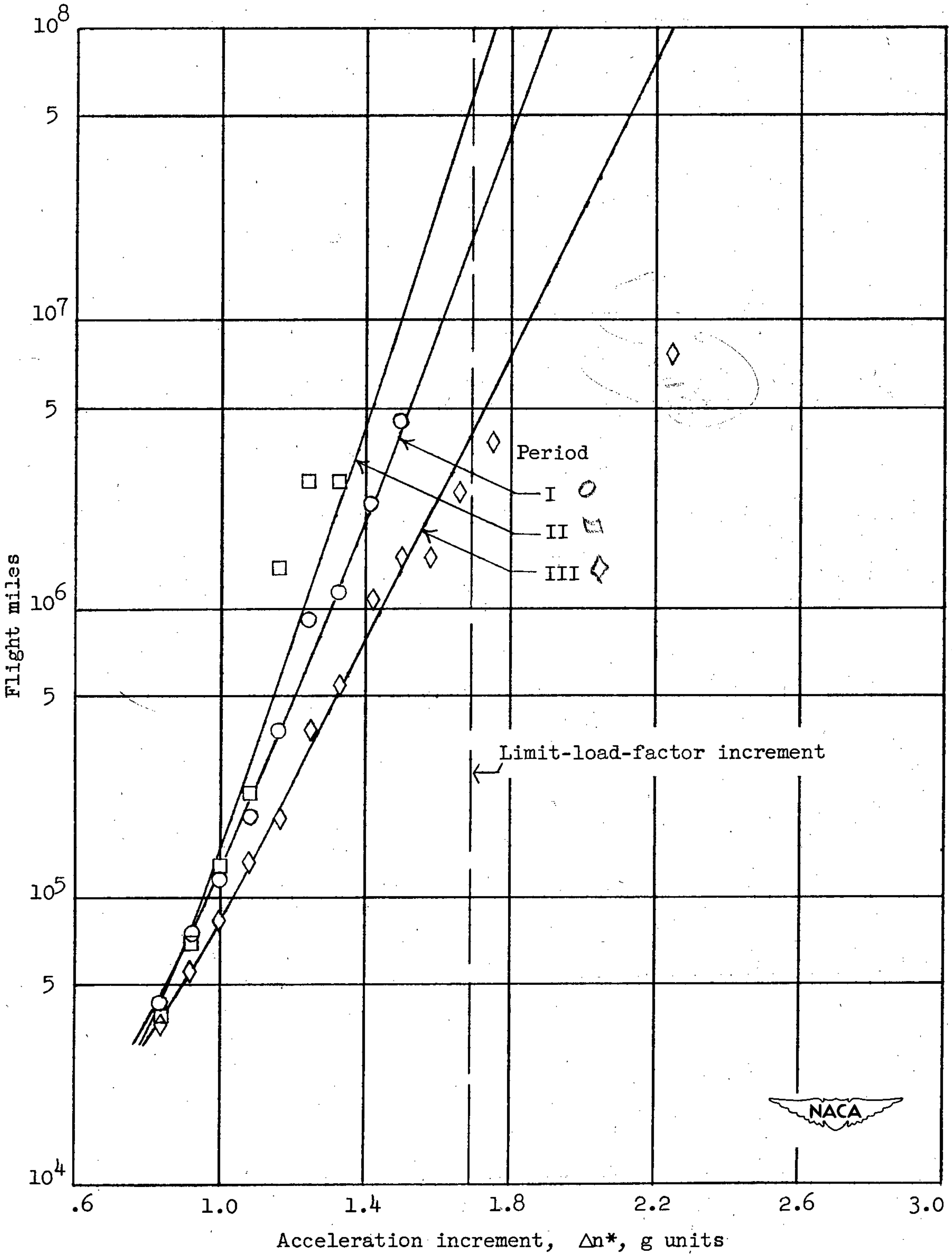

Figure 6.- Average flight miles required for a maximum acceleration increment to equal or exceed a given value by periods.

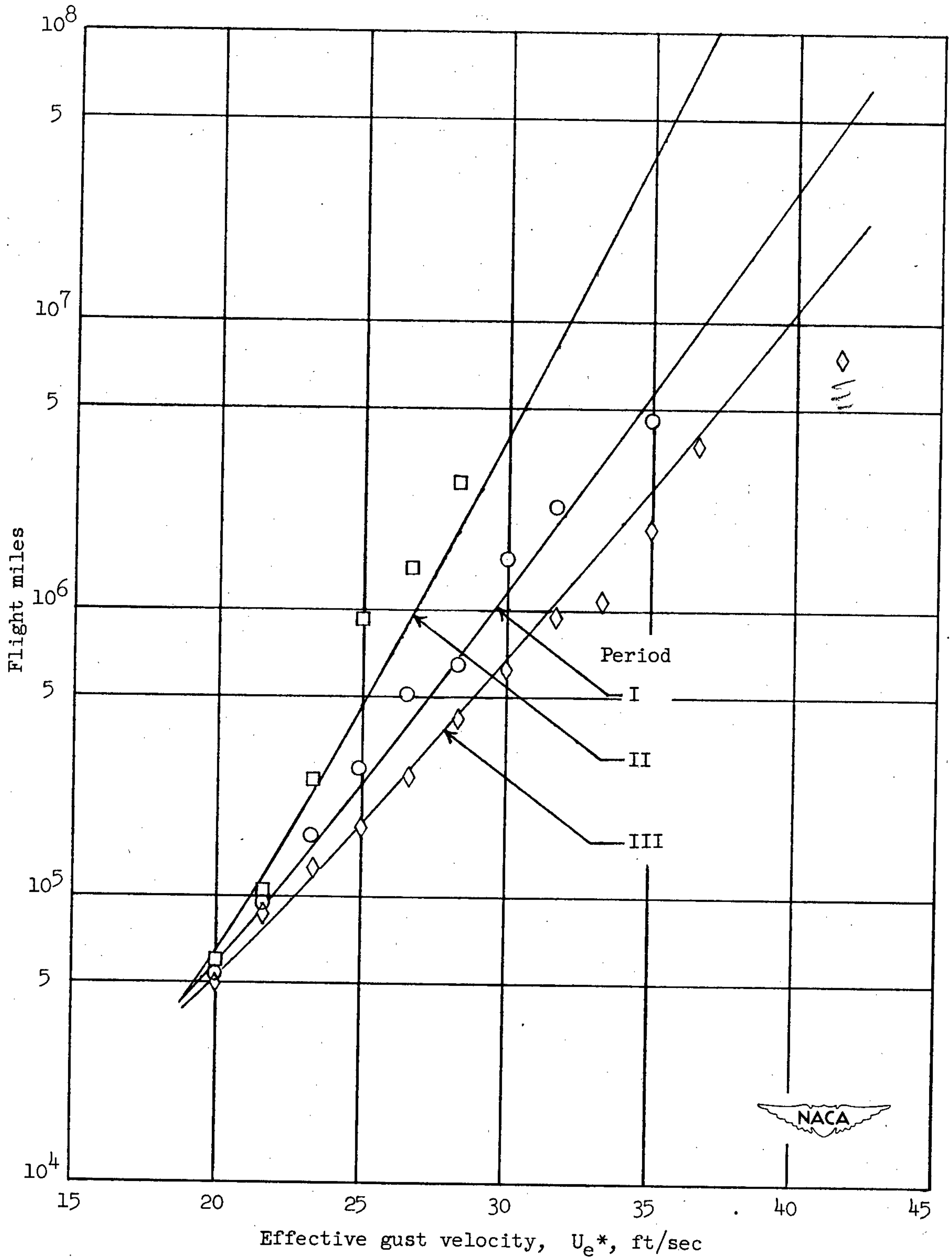

Figure 7.- Average flight miles required for a maximum effective gust velocity to equal or exceed a given value by periods.

NACA TN 2833
National Advisory Committee for Aeronautics.
AN ANALYSIS OF NORMAL ACCELERATIONS AND AIRSPEEDS OF ONE TYPE OF TWIN-ENGINE TRANSPORT AIRPLANE IN COMMERCIAL OPERATIONS OVER A NORTHERN TRANSCONTINENTAL ROUTE. Roy Steiner. November 1952. 23p. diagrs., 4 tabs. (NACA TN 2833)

Normal-acceleration and airspeed data obtained for one type of twin-engine transport airplane in commercial operations over a northern transcontinental route are analyzed to determine the gust and gust-load experiences of the airplane. The acceleration increments experienced equaled or exceeded the limit-gust-load factor, on the average, twice (once positive and once negative) in about 7.5 x 10^6 flight miles, and an effective gust velocity of 30 feet per second was equaled or exceeded twice in about 1 x 10^6 flight miles. The data indicate that the

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1. Loads, Gust - Wings (4.1.1.1.3)
2. Gusts, Atmospheric (6.1.2)
3. Operating Problems (7)

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